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Analytic Network Process Model For Sustainable Lean And Green Manufacturing Performance Indicator

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Abstract. Sustainable manufacturing is regarded as the most complex manufacturing paradigm to date as it holds the widest scope of requirements. In addition, its three major pillars of economic, environment and society though distinct, have some overlapping among each of its elements. Even though the concept of sustainability is not new, the development of the performance indicator still needs a lot of improvement due to its multifaceted nature, which requires integrated approach to solve the problem. This paper proposed the best combination of criteria en route a robust sustainable manufacturing performance indicator formation via Analytic Network Process (ANP). The integrated lean, green and sustainable ANP model can be used to comprehend the complex decision system of the sustainability assessment. The finding shows that green manufacturing is more sustainable than lean manufacturing. It also illustrates that procurement practice is the most important criteria in the sustainable manufacturing performance indicator.

Keywords: Analytic Network Process, sustainable manufacturing, performance indicator, lean manufacturing, green manufacturing.
PACS: 88.05 Lg

INTRODUCTION

At present, the concept of sustainability is being popularized today and started to emerge everywhere and it includes manufacturing industries. The concept of sustainable manufacturing emerged in manufacturing due to its current practice which is being held responsible as one of the main cause for today's environmental deprivation [1]. Sustainability is being defined by [2] as "*the development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" and being further categorized into three inter dependent yet mutually supporting pillars of economic, environmental and social as shown in Figure 1 [2, 3]. On the other hand, the interpretation of sustainable manufacturing is suggested by [4] as "*the creation of manufactured products that use materials and processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound".*

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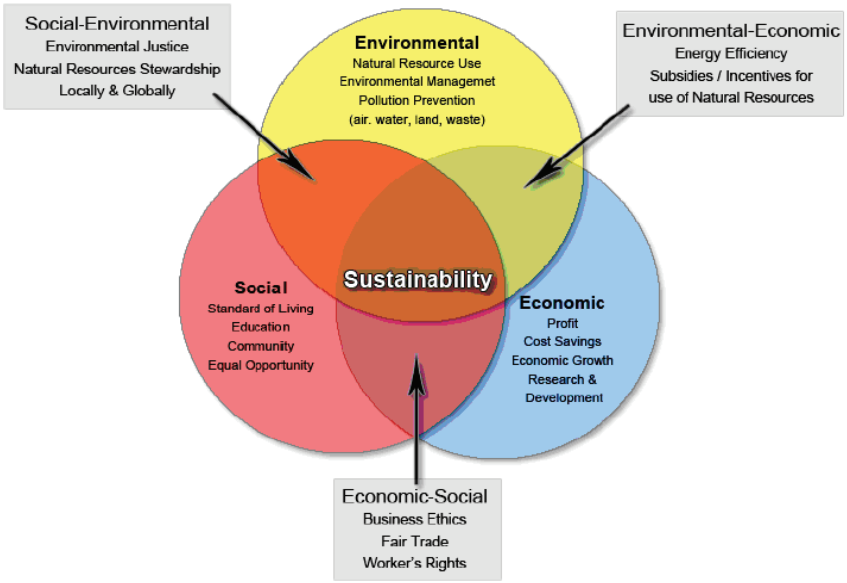

FIGURE 1: Three Pillars of Sustainability

Sustainable manufacturing is the most complex yet challenging manufacturing paradigm compared to previous manufacturing paradigm of mass production; lean manufacturing and green manufacturing etc [1] The sustainable thinking insisted manufacturing practice to benefit the elements of economic, environment and social aspect in a balanced manner [1, 2]. Prior to this relatively new paradigm, the development of sustainable manufacturing performance indicators is highly sought by academicians and industry practitioners to monitor the actual progress of the practice [5, 6, 7]. However, the task to find a perfect balance in terms of benefits is claimed to be vague, confusing and tedious in which it become a challenge to develop a robust sustainable manufacturing performance indicator [5, 6, 8, 9].

The sustainable manufacturing indicators repository developed by [10] contains 14 set of indicators that maybe applied to the setting of manufacturing. In spite of that, not all of these indicators are exactly made for the conformance of manufacturing. From these 14 indicators, only Ford Product Sustainability Index and GM Metrics for Sustainable Manufacturing are being made to comply with the manufacturing requirements. In addition, 2005 and 2006 Environmental Performance Indicator, ISO 1403, Environmental Indicators for European Union, and Eco-Indicators 1999 are only focusing on the environment pillar of sustainability which does not sufficient to address the sustainability concepts in a holistic manner. In addition, other general sustainability indicators though comprehensive, can be accustomed to the application of manufacturing.

LEAN AND GREEN

According to [11, 12] lean manufacturing and green manufacturing has shown some fuzzy evidence in terms of their affiliation with sustainable manufacturing.

Though [11, 13, 14] have shown that lean and green have some sustainability influences, it is still not precisely known on the types of connections among their component. As most of the manufacturing companies today have already implemented the lean or green manufacturing, it is desirable if there exists studies which can demonstrate what is necessary to aid the transformation of the companies towards a more sustainable manufacturing practice. Though several sustainable performance indicators have been developed, the relative importance or influence among the indicators should be further explored to assist on the understanding among the relationships among sustainability components [8, 15]. In this study, we investigate on the relative importance among the sustainability indicator components as well as their influence with the manufacturing systems of lean and green.

ANP MODEL OF SUSTAINABLE MANUFACTURING INDICATOR

In this study we prefer to construct our model on the precinct of Global Reporting Initiative (GRI) latest guideline which is the G4 Sustainability Reporting Guidelines. Our justification is based on three facts. The first one is that GRI is a pioneer and a well-known organization in the sustainability field. GRI promotes the use of sustainability reporting that is widely used around the world as a way for organizations to become more sustainable and contribute to sustainable development. It provides metrics and methods for measuring and reporting sustainability-related impacts and performance. Next, the G4 is being made to be standard and thorough compared to the other indicators. It means that G4 can be applied to all types of companies and organizations and this proves to be essential as a basic foundation in our model development. The last justification is based on the fact that G4 managed to construct more social indicators which [8] asserted to be insufficient and vague in the context of sustainable manufacturing.

This study designates the best combination of strategic and control criteria utilized from the G4 Sustainability Reporting Guidelines to form a robust sustainable performance indicator for manufacturing industry via the utilization of Analytic Network Process (ANP) as shown in Figure 1. AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, whereas ANP structures it as a network. ANP also allows the interdependence among the criteria considered which is more applicable to a real world decision problem [16].

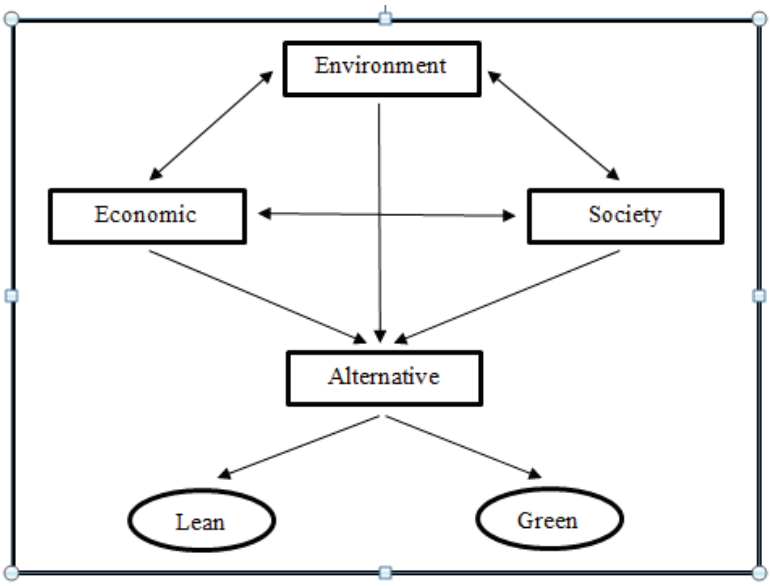

FIGURE 2: ANP Model for Sustainable Lean and Green Manufacturing Performance Indicator

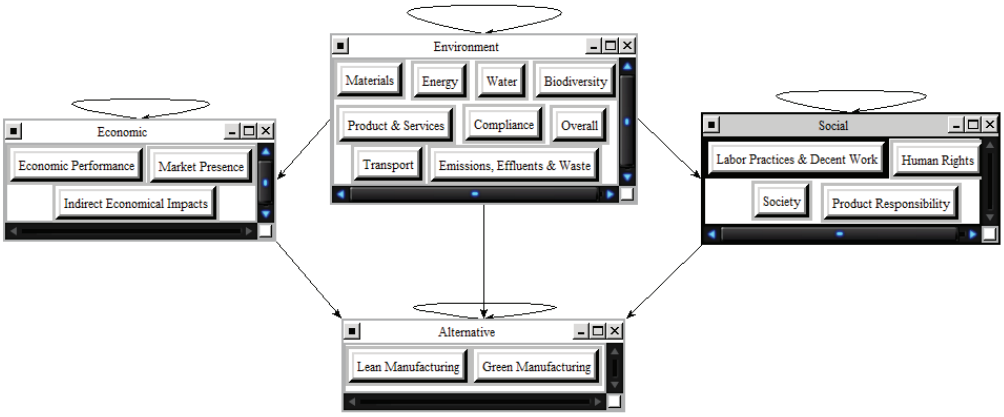

FIGURE 3: SuperDecision Implementation of ANP Model

From the sustainability point of view, the complex and unstructured elements involved in the three originally separate paradigms can be generalized with the application of this method. The ANP model in this study shown in Figure 2 is being developed with the assistance of the SuperDecisions software as exhibited in Figure 3. The economic, environment and social criteria from G4 Sustainability Reporting Guideline is being made as the control criteria whereas the lean and green manufacturing is constructed as alternatives for the respective criteria.

RESULTS AND DISCUSSION

The weight of the relative importance for the ANP model is acquired from 4 academicians and 2 practitioners were aggregated using geometric mean. From the response, local ranking and global ranking of the sustainability criteria for economic, environment and social dimension is determined as shown in Table 1.

TABLE 1. ANP Model Results

	Criteria	Local Weight	Cluster Ranking	Global Weight	Overall Ranking
Economic	Economic Performance	0.23822	2	0.056229	5
	Indirect Economic Impacts	0.06902	3	0.016291	13
	Market Presence	0.05681	4	0.01341	14
	Procurement Practice	0.63595	1	0.15011	3
Environment	Biodiversity	0.00552	12	0.00091	22
	Effluents and Waste	0.01951	10	0.003218	20
	Emissions	0.01953	9	0.003222	19
	Energy	0.02157	8	0.003558	18
	Environment Compliance	0.13629	2	0.022485	9
	Environmental Grievance Mechanism	0.03879	7	0.006399	17
	Materials	0.11329	4	0.018691	11
	Overall Environmental	0.12168	3	0.020074	10
	Product & Services	0.07943	6	0.013105	15
	Supplier Environmental Assessment	0.32459	1	0.053551	6
	Transport	0.10177	5	0.01679	12
	Water	0.01804	11	0.002976	21
Social	Human Rights	0.05172	3	0.011476	16
	Labor Practices & Decent Work	0.61387	1	0.136216	4
	Product Responsibility	0.1962	4	0.043536	7
	Society	0.13821	2	0.030668	8
Alternatives	Green Manufacturing	0.56434	1	0.212803	1
	Lean Manufacturing	0.43566	2	0.164279	2

Based on given sustainability criterion, the green manufacturing is shown to be more sustainable than lean manufacturing. The result also demonstrated that procurement practice is the most important criteria to be considered by the manufacturing organization in order for them to be more sustainable. This follows by labor practices and decent work and economic performance. Biodiversity is shown to be the least important criteria followed by water and effluents and waste.

CONCLUSION

In this paper, we reviewed the existing sustainable manufacturing indicators and applied the ANP approach to the sustainability criteria as provided from G4 Sustainability Reporting Guidelines. This ANP model can be used as a basic model to comprehend the relative importance between the sustainability indicators components and their influence with lean and green manufacturing systems. This study will continue with the acquisition of weight for the relative importance from more experts to further validate the weight and the ranking of indicators components as initiated in the ANP model. The expected outcome in this study will be a model which can be used to guide the decision making process of the sustainability indicators selection and prioritization for lean and green manufacturing performance

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